URANIUM IN CANADA

1989

ASSESSMENT SUPPLY and REQUIREMENTS

THE ENERGY OF OUR RESOURCES

THE POWER OF OUR

URANIUM in CANADA

1989 ASSESSMENT OF SUPPLY AND REQUIREMENTS

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Preface

Assessing Canada's uranium resources as of January 1, 1989, this report reviews the developments in the Canadian uranium industry during 1987 and 1988, and through the second quarter of 1989. To clearly reflect this coverage, the 1989 date has been used in the report title. The 1989 report, therefore, represents the latest formal release in this biennial series, following the 1986 report.

Acknowledgments

The Uranium Resource Appraisal Group is grateful to the uranium mining industry of Canada for its assistance and co-operation in contributing data for this report, and to the representatives of the Ontario Ministry of Northern Development and Mines, and of Saskatchewan Energy and Mines, for assistance in assessing uranium resources within their respective domains.

The interpretation of uranium resource data presented herein was made possible by the efforts of Messrs. A. Fustos, A. Boyer, D. Walsh and R. Boyle of EMR's Canada Centre for Mineral and Energy Technology (CANMET), and Messrs. V. Ruzicka, S.S. Gandhi, R.T. Bell and N. Prasad of EMR's Geological Survey of Canada (GSC).

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CANADIAN URANIUM INDUSTRY FACT SHEET

	1988	1987	1986	1985
Estimates of Known Uranium Resources Recoverable from Mineable Ore (000 tU)	544	559	567	545
Primary Production (tU)				
Ontario - Elliot Lake (Rio Algom)	2 349	2 405	2 813	2 840
- Elliot Lake (Denison)	1 876	1 809	2 015	2 112
Saskatchewan - Key Lake (Cameco/Uranerz)	4 629	5 199	4 834	4 270
- Rabbit Lake (Cameco)	2 679	2 193	1 227	824
- Cluff Lake (Amok/Cameco)	860	829	834	834
Total Primary Production (tU)	**12 393***	**12 435**	**11 723**	**10 880**
Share of Western World Output (%)	34	34	32	31
Domestic Reactor Requirements (tU)	1 700	1 500	1 400	1 300
Ontario Producer Shipments (tU)	4 543[P]	4 901	4 752	4 499
Value of Shipments ($C millions)	523[P]	581	566	553
Saskatchewan Producer Shipments (tU)	8 690[P]	8 711	6 750	5 942
Value of Shipments ($C millions)	585[P]	601	476	450
Total Producer Shipments (tU)	**13 233[P]**	**13 612**	**11 502**	**10 441**
Value of Shipments ($C millions)	**1,108[P]**	**1,182**	**1,042**	**1,002**
Average Price for Deliveries Under Export Contracts - ($C/kgU)	79	79	89	91
- ($US/lb U_3O_8)	25	23	25	26
Spot Sales Proportion of Deliveries Under Export Contracts (%)	13	35	21	20
Average Annual "NUEXCO" Spot Market Price ($US/lb U_3O_8)	14.55	16.78	17.00	15.60
Canadian Uranium Under Export Contracts Reviewed/Accepted during the Year (tU)	11 097[r]	7 247[r]	9 687[r]	11 440[r]
Actual Exports of Uranium of Canadian Origin (tU)	10 434	12 789	8 443	7 888
Uranium Exploration Expenditures in Canada ($C millions)	59	37	33	32
Employment as of December 31 (Mine + Mill + General)	4,730	4,825	5,080	5,333

* *In 1988, an additional 73 tU was recovered by Elliot Lake producers from refinery/conversion facility wastes.*

[P] *preliminary data*

[r] *revised*

EXECUTIVE SUMMARY

Canada is the leading producer and exporter of uranium in the world. In 1988, Canada's five uranium producers reported output of concentrate containing a record 12 470 metric tons of uranium (tU), or about one-third of total Western world production. In 1988, shipments made by the five producers exceeded 13 200 tU, valued at $Cdn 1.1 billion. Most of Canada's uranium output is available for export for peaceful purposes, as domestic requirements represent about 15 per cent of Canadian production.

Despite market uncertainties in 1988, Canada's six uranium marketers signed new sales contracts for over 11 000 tU. The bulk of this total is destined for the United States, which is now Canada's major uranium export customer. The recent implementation of the Canada/U.S. Free Trade Agreement [1/2] benefits both countries, allowing their uranium industries to develop in an open, free-market environment.

Annual exports of Canadian-origin uranium peaked in 1987 at 12 790 tU, falling back to 10 430 tU in 1988. Forward domestic and export contract commitments were more than 70 000 tU and 60 000 tU, respectively, as of early 1989.

In 1988, the uranium industry in Canada was restructured and consolidated by merger and acquisition. Of note was the creation of Cameco - A Canadian Mining & Energy Corporation. Three uranium projects were also advanced significantly. Canada's new policy on non-resident ownership in the uranium mining sector, announced at year-end 1987 and designed to encourage both Canadian and foreign investment, should greatly facilitate efforts to finance the development of recent Canadian uranium discoveries.

With a large share of the world's known uranium resources of economic interest, Canada remains the focus of international uranium exploration activity. The Athabasca Basin in northern Saskatchewan is the primary target for the discovery of high-grade, low-cost uranium deposits.

Canadian uranium exploration and development efforts in 1987 and 1988 led to the discovery of significant new uranium resources, but these did not fully replace the record output over the two-year period. Therefore, the estimate of overall resources as of January 1989 was down by 4 per cent from January 1987, as shown in the table above.

Principal Resource Categories	*Tonnes U* Recoverable From Mineable Ore*	
	1/1/87	**1/1/89**
Measured	70 000	65 000
Indicated	235 000	224 000
Inferred	262 000	255 000
Total	**567 000**	**544 000**

**One metric ton (tonne) of elemental uranium (U), written as tU, is equivalent in terms of uranium content to 1.2999 short tons of uranium oxide (U_3O_8).*

Uranium exploration expenditures in Canada reached $Cdn 37 million in 1987, and jumped to $59 million in 1988. The increase is due largely to the test mining programs under way at the Cigar Lake and Midwest projects in Saskatchewan. Advanced underground exploration included shaft sinking at both sites in 1988. Although well below the $130 million total reported for 1979, expenditure levels in 1988 were still significant and are expected to remain above the $50 million level in 1989. Combined exploration and surface development drilling in 1987 and 1988 reached 164 000 m and 202 000 m, respectively, over 85 per cent of which was in Saskatchewan.

The short-term outlook for the uranium industry is somewhat uncertain. From 1987 to mid-1989, uranium spot market prices fell to all-time lows in constant dollar terms, and there is little immediate sign of relief. Canadian uranium output in 1989 could be well below the 1988 level as poor market conditions have led to the announcement of employment cuts by Cameco, and longer than usual "summer" closures by some producers. Based only on existing production centres, Canada's projected annual uranium production

capability could well fall below 12 000 tU before the late 1990s. However, should market conditions warrant, and given enough lead time, output capability could be increased beyond 15 000 tU by the latter half of the 1990s.

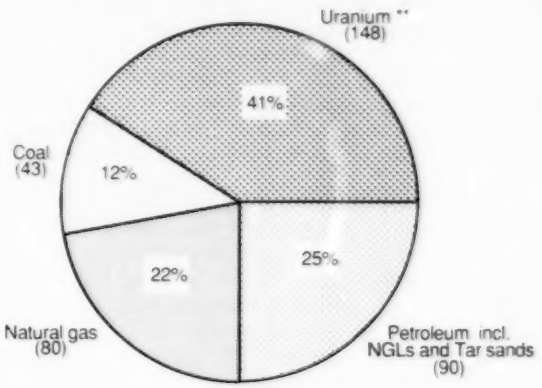
While most analysts predict the need for production from new uranium projects commencing in the mid-1990s, the precise timing of these needs is uncertain. Uranium requirements in the Western world are projected to exceed 47 000 tU annually before the year 2000.

For the medium term, Canada's known uranium resources are more than sufficient to meet the 30-year fuel requirements of those reactors in Canada that are either in operation now or expected to be in service by the late 1990s. A large portion of Canada's known uranium resources is thus surplus to domestic needs and available for export.

Over the longer term, there is significant potential for discovering additional uranium resources in Canada. With increasing demand for uranium, much of this potential will no doubt be realized and developed. Canada is assured of being able to supply its own needs while contributing to those of its trading partners for many years to come.

The importance of uranium as an energy source is shown in Figure 1, which compares the thermal energy equivalents of Canada's 1988 output of fossil fuels with that of uranium based on the once-through nuclear fuel cycle. As indicated, Canada's uranium production is equivalent, in thermal energy terms, to two-thirds of Canada's combined production of petroleum, natural gas, and coal. Advanced fuel cycles, such as the reprocessing and recycling of nuclear reactor fuel, could increase greatly the energy produced from each kilogram of uranium mined.

Figure 1 : *Canadian Production of Mineral Fuels in 1988 (MTOE)**



* Thermal Energy Equivalents, Measured in Millions of Tonnes of Oil Equivalents, i.e., MTOE

** Used in a "Once - Through" Nuclear Fuel Cycle

1 MTOE is equivalent to :
84 Tonnes Uranium
7.58 Million Barrels Oil
1.111 Billion cu.m. Natural Gas
1.5 Million Tonnes Hard Coal
3.0 Million Tonnes Soft Coal
42 Petajoules

SOURCE : UNEB/EMR

Part 1. SHORT-TERM PERSPECTIVE

1. SUPPLY

A) Supply Sources

Measured, Indicated and Inferred Resources

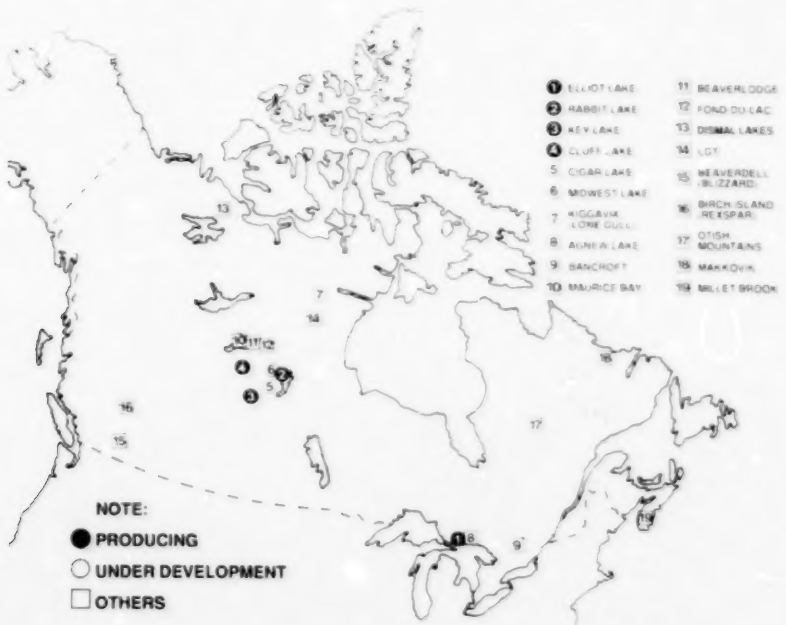
Canadian uranium supply over the next 10 to 15 years will be drawn from known resources, estimates of which are divided into three major categories, measured, indicated and inferred, that reflect different levels of confidence in the reported quantities. Most of these resources are associated with deposits identified in Figure 1. The current estimates of resources in these three categories, prepared by EMR's Uranium Resource Appraisal Group (URAG), are presented in Table 1.

A comparison of current estimates of Canadian uranium resources with those reported previously [3] (see Table 1), indicates that resource additions from new discoveries did not fully replace the record output over the two-year assessment period. The net decline in all three resource categories reflects actual production draw-down of the reserves, primarily those at lower cost levels.

Figure 2 locates the principal uranium deposits in Canada.

Of Canada's combined measured, indicated and inferred resources presented in Table 1, almost half occur in unconformity-related type deposits, primarily in northern Saskatchewan. These contain either monometallic (Eagle Point) or polymetallic (Key Lake and Cigar Lake) mineralization associated with the sub-Athabasca unconformity.

Figure 2 : *Uranium Deposits in Canada*



SOURCE : UNEB/EMR

In the monometallic deposits, the mineral pitchblende prevails, whereas in the polymetallic deposits uranium-nickel-cobalt assemblages are usually predominant. Average grades can vary from below 1 per cent U to between 2 and 5 per cent U, while in parts of certain deposits (Cigar Lake) grades can exceed 10 per cent U.

Most of Canada's other known uranium resources occur in quartz-pebble conglomerates, primarily in the Elliot Lake area of Ontario. The ore occurs in several beds and grades on average between 0.05 and 0.1 per cent U.

Table 1. **Estimates of Canada's Uranium Resources Recoverable from Mineable Ore[1], 1/1/87 and 1/1/89**

	(Thousands of tonnes of uranium)					
Price ranges within which mineable ore is assessed[2]	**Measured**		**Indicated**		**Inferred**	
	1/1/87	*1/1/89*	*1/1/87*	*1/1/89*	*1/1/87*	*1/1/89*
A	46	41	107	98	112	109
B	1	2	95	94	99	95
A + B	47	43	202	192	211	204
C	23	22	33	32	51	51
A + B + C	70	65	235	224	262	255

1. Actual or expected losses in mining recovery and ore processing have been accounted for; these factors were individually applied to resources tributary to existing or prospective production centres. In underground operations, mineable ore is generally 75 to 85 per cent of the ore-in-place; higher mining recoveries are achievable in open-pit operations. Ore-processing recoveries in Canada normally range from 90 to 97 per cent; Canada's weighted average mill recovery for existing conventional uranium operations was 96 per cent in 1988.

2. The price ranges are (A) $100/kgU or less, (B) between $100 and $150/kgU and (C) between $150 and $300/kgU. The Canadian dollar figures reflect the price of a quantity of uranium concentrate containing 1 kg of elemental uranium. The prices were used in determining the cut-off grade at each deposit assessed, taking into account the mining method used and the processing losses expected. The price of $100/kgU was used by URAG to illustrate those resources that were of economic interest to Canada in 1986 and 1988.

$1/lb U_3O_8 = $2.6/kgU

B) *Uranium Availability*

Existing Operations [4]

In February 1988, the Canadian and Saskatchewan governments agreed to a merger and subsequent privatization of Eldorado Nuclear Limited and Saskatchewan Mining Development Corporation, their respective Crown companies in the uranium business. The merger, effective September 30, 1988, created a large, integrated uranium mining and processing company with headquarters in Saskatoon, Saskatchewan. Known as Cameco - A Canadian Mining & Energy Corporation, the new firm employs more than 1,000 persons, has assets of $1.5 billion, and rivals the French firm Compagnie Générale des Matières Nucléaires (COGEMA) as the world's foremost fully integrated uranium producer.

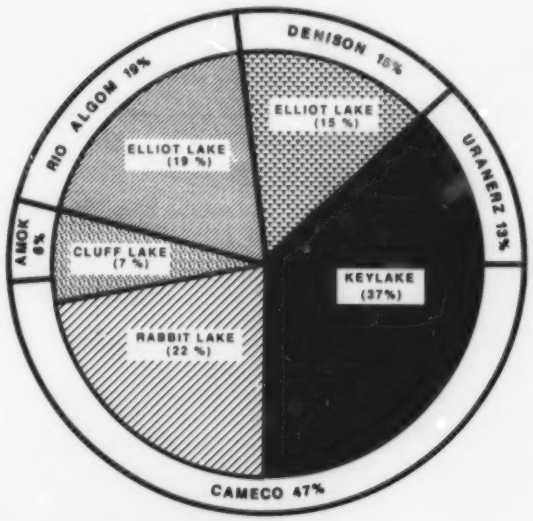
At year-end 1988, Canada had five primary uranium producers: Rio Algom Limited, Denison Mines Limited, Cluff Mining, Key Lake Mining Corporation (KLMC) and Cameco. Figure 3 shows the output and ownership of Canada's production centres in 1988. The key data for these uranium production centres are shown in Table 2.

Rio Algom and Denison operate conventional underground mines at Elliot Lake, Ontario. Both companies also recover uranium using in-place leaching techniques. The other three producers are located in northern Saskatchewan, in the Athabasca Basin area. Cameco and KLMC produce from open-pit mines whereas Cluff Mining produces from both open-pit and underground mines.

Primary uranium output exceeded 12 390 tU in 1988, and with the addition of 73 tU recovered in Ontario from Cameco's refinery and conversion facility wastes, total uranium production in Canada reached a new record level. Primary production was up in Ontario but declined in Saskatchewan.

Preliminary estimates of 1988 shipments of uranium made by Canada's producers was 13 233 tU, valued at $1.1 billion. Differences between annual production and shipment figures reflect inventory quantities.

Figure 3 : *Canadian Uranium Production and Ownership, 1988*



1988 PRIMARY PRODUCTION ≈ 12 400 TONNES U

SOURCE : UNEB/EMR

Elliot Lake, Ontario, Operations

In 1988, Denison Mines Limited and Rio Algom Limited continued augmenting primary production both from in-place (underground) leaching and from processing refinery/conversion wastes. Denison established underground access to its adjoining Canuc property ahead of schedule, and started mining there in 1989.

Rio Algom continued development work in 1989 on the Milliken, Lacnor, and Nordic properties, that are tributary to its Stanleigh operation. Dewatering of the Milliken mine began in May 1988 and could be completed by 1990.

Efforts to reduce costs and to increase overall productivity are continuing at all four operating production centres at Elliot Lake. Both companies are looking beyond their producing mines for future uranium supply. Denison is assessing the feasibility of mid-1990s output at its Midwest project in northern Saskatchewan, and is maintaining its Koongarra property in Australia in good standing. In the United States, Rio Algom has purchased the Wyoming uranium properties of Kerr-McGee Corporation, and its wholly owned Quivera Mining Company.

Figure 4 shows the Elliot Lake, Ontario, uranium-producing district.

Table 2. **Operational Characteristics of Existing Canadian Uranium Production Centres in 1988**

Company and plant location	Deposit type[a] and mining method[b]	Ore-processing plant*			
		Method[c] and recovery (%)	Rated mill capacity/Ore throughput (tonnes/day)	Annual ore milled (tonnes)	Average ore grade processed (% U)
Cluff Mining-Phase II Cluff Lake, Saskatchewan	Ucon/OP/UG	AL/SX/96	+900/1 000	183 000	0.49
Denison Mines Limited Elliot Lake, Ontario	Cong/UG/IPL	AL/IX/94	7 700/7 700	2 572 000	0.08
Cameco - A Canadian Mining & Energy Corporation Rabbit Lake, Saskatchewan	Ucon/OP	AL/SX/96	1 800/1 600	388 000	0.72
Key Lake Mining Corporation Key Lake, Saskatchewan	Ucon/OP	AL^2/SX/98	+700/+700	242 000	1.94
Rio Algom Limited Elliot Lake, Ontario					
■ Quirke mill	Cong/UG/IPL	AL/IX/94	5 000/4 500	1 525 000	0.08
■ Panel mill	Cong/UG/IPL	AL/IX/95	3 000/3 000	978 000	0.08
■ Stanleigh mill	Cong/UG/IPL	AL/IX/95	+4 500/2 900	652 000	0.07

* *Figures rounded*

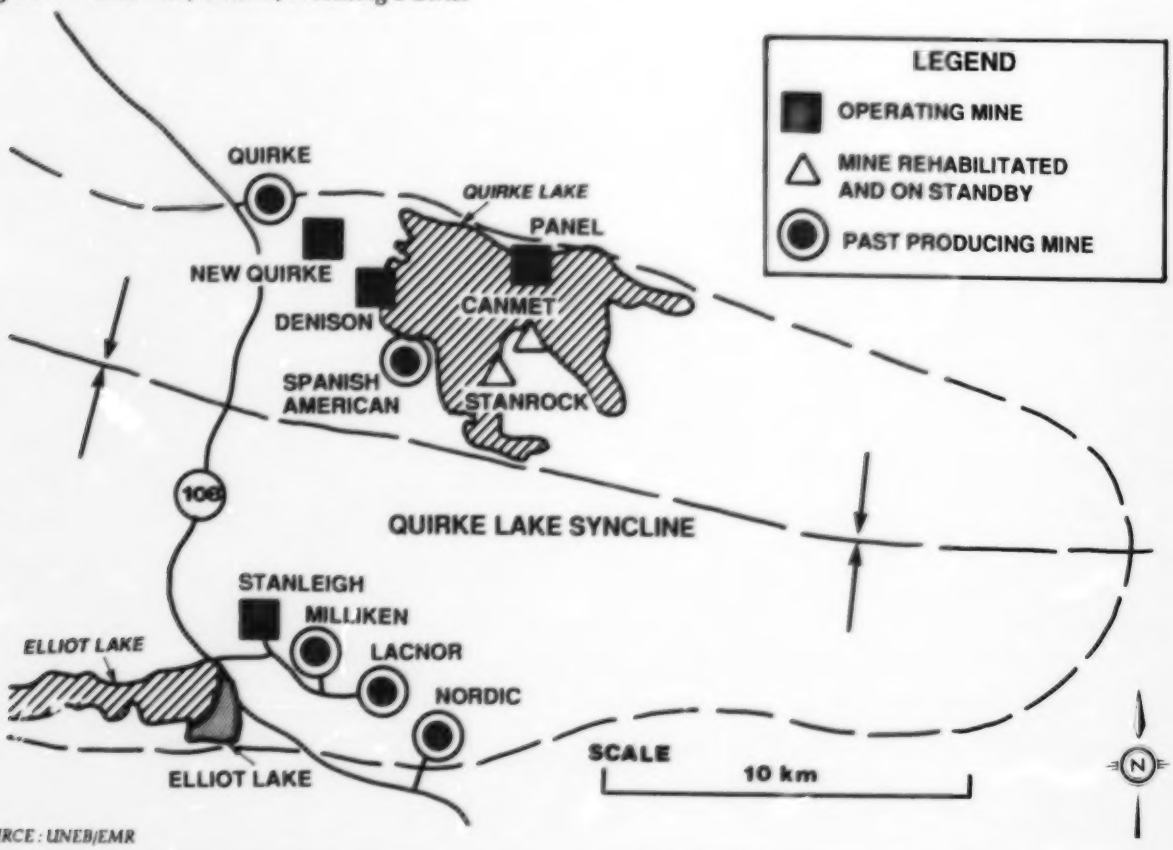
[a] *Deposit types: conglomeratic (Cong), unconformity related (Ucon)*

[b] *Mining methods: underground (UG), open-pit (OP), in-place leaching (IPL)*

[c] *Ore-processing methods: acid leaching (AL), two-stage acid leaching (AL^2), ion exchange (IX), solvent extraction (SX)*

Sources: Corporate annual reports and the Atomic Energy Control Board

Figure 4 : *Elliot Lake, Ontario, Producing District*



SOURCE : UNEB/EMR

Athabasca Basin, Saskatchewan, Operations

At the Rabbit Lake operation, Cameco received final approval in January 1988 for development of its Collins Bay A and D, and Eagle Point deposits. Although A and D could be mined in about a year as open pits, it is expected that the larger, underground Eagle Point mine will be brought on stream first, as it has output potential well into the next century.

Late in 1988, Uranerz Exploration and Mining Limited acquired Noranda Exploration Company, Limited's one-third interest in Eagle Point North; Cameco owns the other two-thirds and all of Eagle Point South.

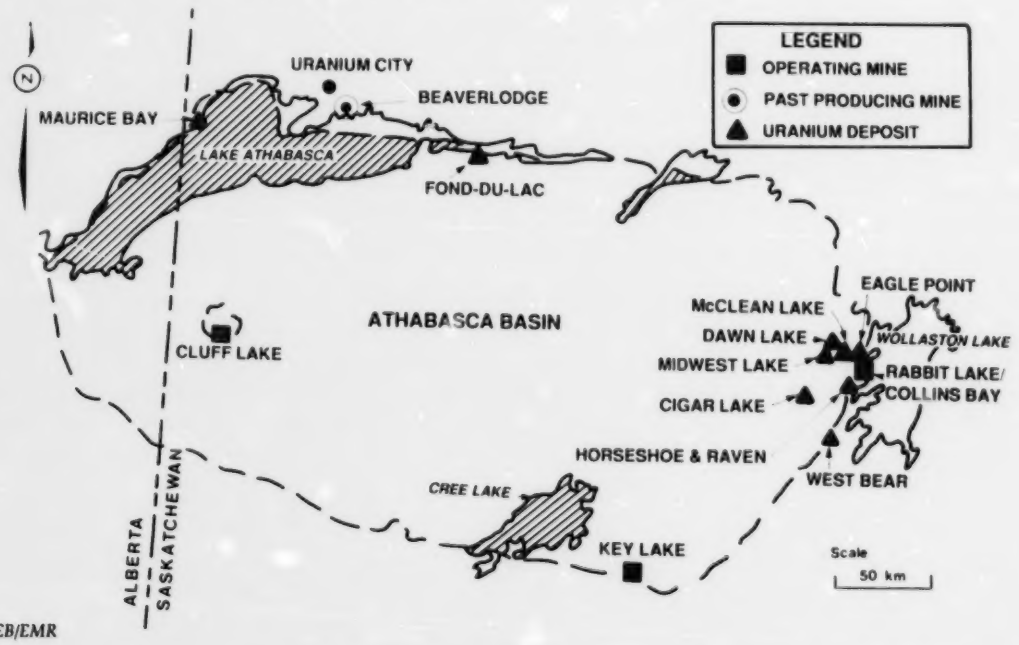
In March 1989, Cameco announced a six-month shutdown of the Rabbit Lake mill, beginning in July 1989, and the termination of 96 minesite jobs. The mill will be upgraded and development work on the Eagle Point South deposit will commence.

At Cluff Lake, some 5 000 tU were discovered between 1984 and 1987, and significant tonnages have since been identified in the South Dominique-Janine deposit. The Cluff Mining partnership received final government approvals in October 1988 to develop its Dominique-Janine open pit prior to ore depletion at the Claude open pit in 1989; the Dominique-Peter underground mine and the Claude open pit both provided millfeed in 1988.

Production at Cluff Lake remains geared to sales. Ore was milled only every second week in 1988, but as the capacity was raised to 1 000 tonnes of ore per day, output surpassed 1987 levels. The announcement in mid-1989 of an extended mill closure could affect production in 1989 and 1990.

Figure 5 shows the major uranium deposits of the Athabasca Basin in northern Saskatchewan.

Figure 5 : *Athabasca Basin, Saskatchewan, Uranium Deposits*



SOURCE : UNEB/EMR

Since early 1987, Cluff Mining has recovered over 250 kg of gold from leach residues produced during Phase I of the operation. The last residues were finally reprocessed in February 1988, the special circuit decommissioned by April, and the last bullion was poured in May 1988.

As Key Lake Mining Corporation decommissioned the Gaertner open pit in 1988, it was preparing the larger Deilmann orebody for mining in 1989; stockpiled Gaertner ore was fed into the mill during 1988. Following the summer shut-down for mill inspection, throughput was raised to achieve the 4 600 tU output target for the year. Because the Deilmann ore is more contaminated with molybdenum than was Gaertner ore, a special mill circuit was installed in mid-1989 to remove the molybdenum, so that product quality could be maintained.

In late March 1989, Cameco and KLMC partner Uranerz Exploration and Mining Limited agreed in principle that Cameco will become operator of the Key Lake uranium mine. Operating costs will be reduced by consolidating the Saskatoon-based support services of the Key Lake and Rabbit Lake operations.

About 4,730 employees worked at Canada's seven producing uranium operations as of December 1988 (see Table 3). Of this total, some 2,170 worked in the mines, both open-pit and underground, 610 in the mills, and the balance were noted as general employees. Construction-related and head-office employment is excluded.

***Table 3*. Uranium-Producing Workforce in Canada**

Company *(operation)*	**Employees** *(mine/mill/general)*
Cluff Mining	180
Denison Mines Limited	1,670
Cameco *(Rabbit Lake)*	350
Key Lake Mining Corporation	440
Rio Algom Limited *(Quirke)*	1,050
(Panel)	570
(Stanleigh)	470
Total (December 31, 1988)	**4, 730**

Projected Production Capabilities

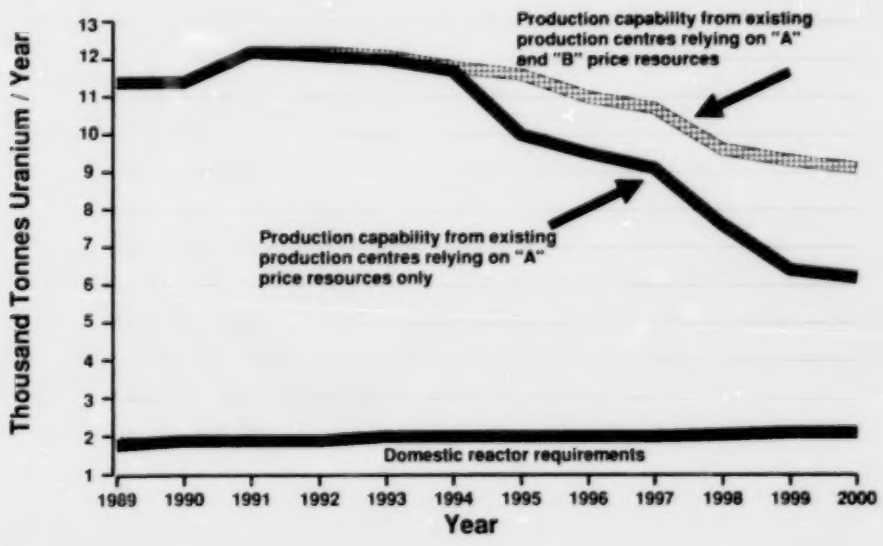
To provide an illustration of uranium availability in the short term, Table 4 and Figure 6 show two projections of Canadian production capability to 1998. These projections of firm production capability are based on existing production centres only, as listed in Table 2. The first projection assumes levels of production that can be practically and realistically achieved under current circumstances from "A" plus "B" priced resources; the second is based on "A" priced resources only.

The lives of some of these production centres could be extended by the exploitation of associated higher-priced resources, or through the addition of resources in the A plus B price range resulting from continued exploration and development work. No firm commitments have been made for the start-up of any production centres beyond those currently in operation.

Table 4. **Canadian Uranium Production Capability From Existing Production Centres**

Year	Projection based on "A" + "B" priced resources	Projection based on "A" priced resources only
	(tonnes U output)	
1989	11 400	11 400
1990	11 400	11 400
1991	12 200	12 200
1992	12 200	12 100
1993	12 100	12 000
1994	11 800	11 700
1995	11 600	10 000
1996	11 000	9 500
1997	10 700	9 100
1998	9 600	7 600

Figure 6 : *Canadian Uranium Production Capability Compared with Domestic Reactor Requirements*



SOURCE : UNEB/EMR

Additional Production Possibilities

In addition to the aforementioned existing operations, other projects could become uranium producers before the end of the 1990s, should market conditions warrant. These projects are noted in Table 5.

Cigar Lake Mining Corporation received exploration and environmental approvals in late 1987 to proceed with a $40 million test mine at Cigar Lake in northeastern Saskatchewan. Sinking of the 500 m-deep shaft began in September 1988; by year-end the surface facilities and head-frame had been installed. In August 1989, the shaft was nearing the 420 m level, from which lateral drifts will be driven for mining tests. These tests will permit final feasibility studies in 1990/91. Assuming the program is successful, and given requisite government approvals, the decision to build a mill or truck the ore to Key Lake for processing could be made in 1992. Output of 4 600 tU/year is foreseen no earlier than 1993. Cigar Lake, the world's largest and richest uranium deposit, has known geologic resources exceeding 150 000 tU, in ore grading an average 10 per cent U.

At the Midwest project, north of Cigar Lake, Denison Mines Limited is also proceeding with an $18 million program to test ground conditions and mining methods at its Midwest Lake deposit. Given environmental approvals in September 1988, Denison collared the 185 m-deep shaft and by year-end had finished the head-frame. In April 1989, the shaft was finished and lateral drifting to the orebody began; test mining is planned for the last half of 1989. Denison and its partners PNC Exploration (Canada) Co. Ltd., Uranerz Exploration and Mining Limited, and Bow Valley Industries Limited are assessing the possibility of mid-1990s output from resources reported to exceed 20 000 tU in ore grading 1 per cent U.

In the Northwest Territories, near Baker Lake, Urangesellschaft Canada Limited hopes to develop its Kiggavik project for production in the mid-1990s. In late 1988, CEGB Exploration (Canada) Ltd. acquired a 20 per cent interest in the project. A decision to proceed with the $200 million project will depend on the uranium market, the results of an environmental review process now under way, and the search for other joint-venture partners.

Urangesellschaft reported that resources sufficient for a ten-year mine life total 15 000 tU, in ore grading 0.4 per cent U. In June 1989, a federal government-appointed Environmental Assessment Review Panel issued guidelines for an Environmental Impact Statement (EIS). The EIS is to be submitted by November 1989, and public hearings will begin in 1990.

Table 5. **Possible Future Uranium Production Centres**

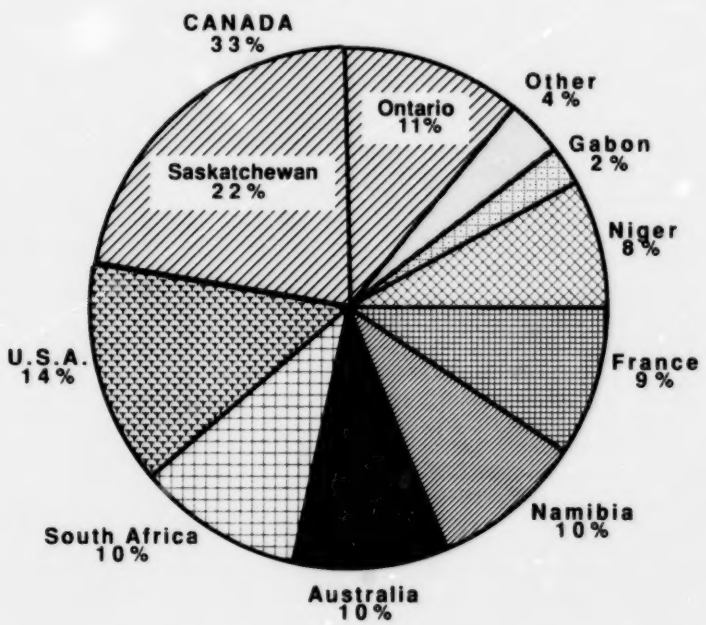
Project	Operator	Deposit type
SASKATCHEWAN		
Cigar Lake	Cigar Lake Mining Corporation	Ucon
Dawn Lake	Cameco	Ucon
McClean Lake	Minatco Limited	Ucon
Midwest Lake	Denison Mines Limited	Ucon
NORTHWEST TERRITORIES		
Kiggavik	Urangesellschaft Canada Limited	Ucon
NEWFOUNDLAND		
Kitts-Michelin	Western Canadian Mining Corporation	VV
BRITISH COLUMBIA		
Blizzard	Norcen Energy Resources Limited	S

Ucon — *Unconformity related*
VV — *Vein and volcanogenic*
S — *Sandstone*

Depending on developments in the international uranium market, certain projects noted in Table 5 could be brought on stream to increase total Canadian production capability beyond 15 000 tU annually by the mid-1990s. Costs associated with some of these possible new production centres are currently uncertain.

Figure 7 compares 1988 production of uranium in Canada with that of the other major Western world producers.

Figure 7 : *Western World Uranium Production, 1988*



TOTAL = 37 000 TONNES U (ESTIMATED)

SOURCE : UNEB/EMR

2 . REQUIREMENTS

A) Domestic Nuclear Power Program

The determination of Canada's uranium requirements is based on the estimates of installed nuclear generating capacity shown in Table 6. In mid-1989, Canada's nuclear capacity in operation, or committed for operation by 1993, was about 15 400 megawatts electric net (MWe). In addition, a second Candu unit is envisaged for Point Lepreau, New Brunswick, another four Candu units could be built east of Toronto at Darlington, and talks are under way toward a Candu 3 reactor in Saskatchewan. By the year 2000, total installed capacity in Canada could increase to 16 000 MWe.

Canadian policy on domestic security of uranium supply requires that sufficient uranium be reserved to meet the 30-year fuel requirements of all Canadian nuclear power reactors, existing, committed and planned, for a rolling 10-year period.

The 30-year requirement for this 16 000 MWe of reactor capacity noted above, assessed on the basis of fuel utilization design values for existing stations, is estimated to exceed 60 000 tU. The introduction of improved burn-up characteristics could reduce requirements by about 15 per cent. Annual requirements, including first cores for future reactors, are now expected to grow from 1 800 tU/year in 1989 to about 2 300 tU/year in 2005, as shown in Table 7.

A measure of domestic uranium resource adequacy can be derived by comparing the +60 000-tonne domestic requirement described above with the conservatively adjusted ❖ estimates of recoverable resources of all companies marketing Canadian uranium. As of January 1, 1989, the total of such resources exceeded by a significant margin the sum of the 30-year domestic requirement plus existing contract commitments. *(❖ See Appendix 2.]*

***Table 6*. Nuclear Power Plants in Canada[a]**

Reactors	Owner	Net capacity (MWe)	In-service dates
Pickering 1 to 4	Ontario Hydro	2 060	1971-73
Bruce 1 to 4	Ontario Hydro	3 066	1977-79
Point Lepreau	NB Power*	635	1983
Gentilly 2	Hydro-Québec	638	1983
Pickering 5 to 8	Ontario Hydro	2 064	1983-86
Bruce 5 to 8	Ontario Hydro	3 394	1984-87
Darlington 1 to 4	Ontario Hydro	3 524	1989-92[e]
Total net capacity expected by 1993		**15 381 MWe**	

[a] *as of mid-year 1989*

* *New Brunswick Electric Power Commission*

[e] *expected*

Table 7. **Estimated Annual Canadian Uranium Requirements**[e]

Year	Tonnes U	Year	Tonnes U
1989	1 800	1995	2 000
1990	1 900	2000	2 100
1991	1 900	2005	2 300

[e] *Estimated fuelling requirements for the nuclear power programs of Ontario Hydro, Hydro-Québec, and the New Brunswick Electric Power Commission.*

B) Uranium Sales Commitments

Canadian producers shipped (i.e., delivered to customers' accounts) an estimated 13 233 tU in 1988 valued at $1.1 billion. More than 85 per cent of this total was destined for the export market. The average price of export deliveries in 1988 was about $Cdn 79/kgU. Roughly 13 per cent of all export deliveries in 1988 were under spot sales, compared with some 35 per cent in 1987, 21 per cent in 1986, and only 1.5 per cent in 1982.

Canada's short-term needs are primarily those required for Ontario Hydro's nuclear power program. The utility's two major uranium supply contracts, approved by the Government of Ontario in February 1978, are with Denison Mines Limited and Rio Algom Limited. These contracts could meet the bulk of Ontario Hydro's needs to the early part of the next century, with deliveries scheduled until 2012 and 2020, respectively. Contracts are in place relating to most of the remaining domestic requirements to the end of the century. As of early 1989, total outstanding domestic commitments were in the order of 70 000 tU.

The relative importance of Canada's uranium export customers is shown in Table 8. Since the start of the commercial era in the mid-1960s, more than 185 000 tU have been sold under export contracts in twelve countries. The year-end 1988 total reflects the scheduled deliveries under roughly 225 contracts, one-quarter of which remain active.

Total forward export commitments exceed 61 000 tU, to be delivered in the period 1989 to 2003. Actual 1987 exports reached 12 790 tU, and totalled 10 434 tU in 1988, primarily to the United States, Western Europe and Japan (see Table 9).

Japan has been Canada's most important customer since the early 1960s. Other important markets have been the European Economic Community, other Western European countries and, more recently, the United States. Indeed, in terms of forward-scheduled commitments (see Figure 8), the U.S. is now Canada's major customer.

In 1988, the U.S. negotiated the bulk of the 11 000 tU sales volume with Canadian producers, much of it under long-term contract. Such long-term commitments are critical to the viability of the uranium industry.

Table 8. **Canadian Uranium Under Export Contract**[a]

Country of buyer[b]	Tonnes U
Belgium	3 325
Finland	3 512
France	9 715
Italy	1 115
Japan	25 046
South Korea	6 903
Spain	3 559
Sweden	8 977
Switzerland	154
United Kingdom	8 293
United States	57 718
West Germany	15 126
Total	**143 443**

[a] *The amount of uranium specified in all export contracts reviewed and accepted under Canada's uranium export policy since September 5, 1974. The country totals are adjusted to reflect new and amended contracts as of January 1, 1989.*

[b] *In most cases, indicates country of end-user.*

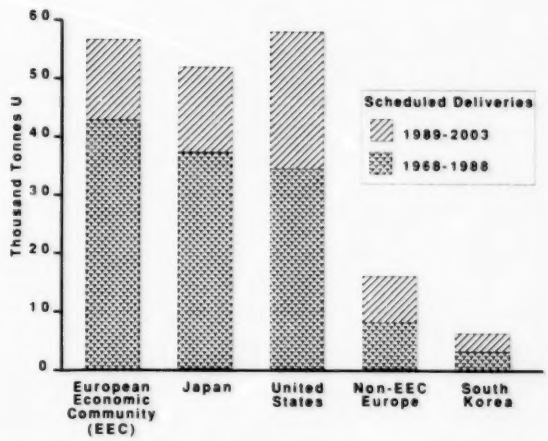
C) *Short-Term Market Outlook*

Predictions about the supply of and demand for mineral commodities are very subjective, and those for uranium are no exception. The outlook over the short term will be influenced by many complex market-related and political factors. Among the more important of these are the actual level of surplus consumer inventories and policies regarding their disposition, the procurement policies of the individual utilities, and the extent to which uranium brokers participate in the spot market.

Other factors of importance will be the outcome of current discussions in Australia on uranium mine development policy, the ability of those producers with stand-by capacity to reactivate their facilities, the success of uranium sales efforts in the West by the U.S.S.R. and People's Republic of China, and, of course, the impact of all these factors on uranium prices.

While most market analysts predict that there will be a need for new uranium production projects commencing in the mid-1990s, the precise timing of this need is uncertain.

Figure 8 : *Scheduled Deliveries of Canadian Uranium for the Export Market*



SOURCE : UNEB/EMR

Table 9. **Exports of Uranium of Canadian Origin**

Country of final destination	Tonnes of contained uranium[a]						
	1982	1983	1984	1985	1986	1987	1988
Belgium	85	-	121	157	63	-	153
Finland	96	179	137	81	116	142	151
France	-	435	525	612	1 013	1 438	964
Italy	143	-	50	53	301	293	-
Japan	718	663	2 436	1 799	816	1 317	717
Netherlands	-	-	-	-	85	40	-
South Korea	74	94	30	194	402	828	874
Spain	110	-	-	-	150	150	100
Sweden	889	613	254	514	449	377	783
Turkey	-	-	-	-	2	-	-
United Kingdom	379	675	692	685	700	824	1 204
United States	4 852[b]	860	2 397	3 524	3 692	6 063	4 682
West Germany	471	490	295	269	654	1 317	806
Total	**7 817**	**4 009**	**6 937**	**7 888**	**8 443**	**12 789**	**10 434**

[a] *Some of this uranium was first exported to intermediate countries, e.g., France, U.S.A. and U.S.S.R., for enrichment and then forwarded to the country of final destination.*

[b] *The bulk of this material represents uranium exchanged by Eldorado Resources Limited (now part of Cameco) in the purchase of the Rabbit Lake operation.*

Source: Atomic Energy Control Board

Part 2. LONGER-TERM PERSPECTIVE

1. SUPPLY

A) Supply Sources

The resources described in Part 1 of this report will provide a base for Canadian production beyond the turn of the century. Although the deposits at some existing production centres will have been depleted by that time, the resources at others are sufficient to permit production well into the next century. In addition, several recent discoveries may also be developed for production before the end of the century; the higher-priced portion of Canada's known resources could also extend production, should market conditions warrant. Beyond these resources there is significant potential for additional discoveries.

It is important to emphasize the distinction between the two categories of "undiscovered" resources, namely prognosticated and speculative. The first refers to uranium that is expected to exist in well-defined geological trends containing known deposits. The speculative category refers to uranium that is thought to exist in unexplored areas or in areas where only occurrences are known. A relatively higher degree of confidence can be placed in estimates of the first type of undiscovered resources because of their proximity to, or close association with, well-delineated deposits.

Table 10. **Estimates of Canada's Prognosticated Resources of Uranium Contained in Mineable Ore**[a]

Price ranges within which mineable ore is assessed[b]	Thousands of tonnes of uranium	
	1/1/87	1/1/89
A	138	154
B	118	120
C	103	107
A + B + C	**359**	**381**

[a] *Uranium recoverable from such ore will be less because of ore-processing losses.*

[b] *Price ranges are (A) $100/kgU or less, (B) $100 to $150/kgU, and (C) $150 to $300/kgU.*

Prognosticated Resources

Estimates of Canada's prognosticated uranium resources as of 1/1/89 are presented in Table 10, together with those as of 1/1/87. The latest URAG assessment of prognosticated resources resulted in an increase of 6 per cent in the overall estimate, and about 12 per cent in the lower ("A") price category. The increases stem mainly from exploration in the Athabasca Basin of Saskatchewan, particularly on the flank of the Dominique Dome, within the Carswell Structure, and on the flank of the Collins Bay Dome, where Minatco made its new discovery known as the Sue Zone. As is evident from the concentration of new discoveries in the Athabasca Basin, the Proterozoic unconformity-related type deposits have become primary exploration targets. Prognosticated resources were also revised at the western extension of the Quirke zone, on the Elliot Lake, Ontario, properties of Rio Algom and Denison.

Speculative Resources

Many other areas of Canada are favourable for the occurrence of uranium resources, in addition to those associated with known uranium deposits. In the current assessment, some resources in the speculative category were moved into the "better-defined" categories, while some were removed as being uneconomic for the foreseeable future. Transfers to the better-defined categories were primarily in the Athabasca Basin region, and represent a 2 per cent loss in the speculative category over the last two years. However, favourable new areas were discovered, and these losses were offset. Estimates made for the current assessment, therefore, show that speculative resources in Canada still amount to 1 million tonnes of uranium.

Estimates of speculative resources are based on Canada's past production, on distribution of known uranium deposits, and on interpretation of geological

features according to conceptual models [5]. They are deemed to be geologically comparable to resources in known deposits that could be mined at a price of $300/kg U or less. Further resources might exist in areas that have not been assessed. Most of the speculative resources are believed to occur in unconformity-related deposits.

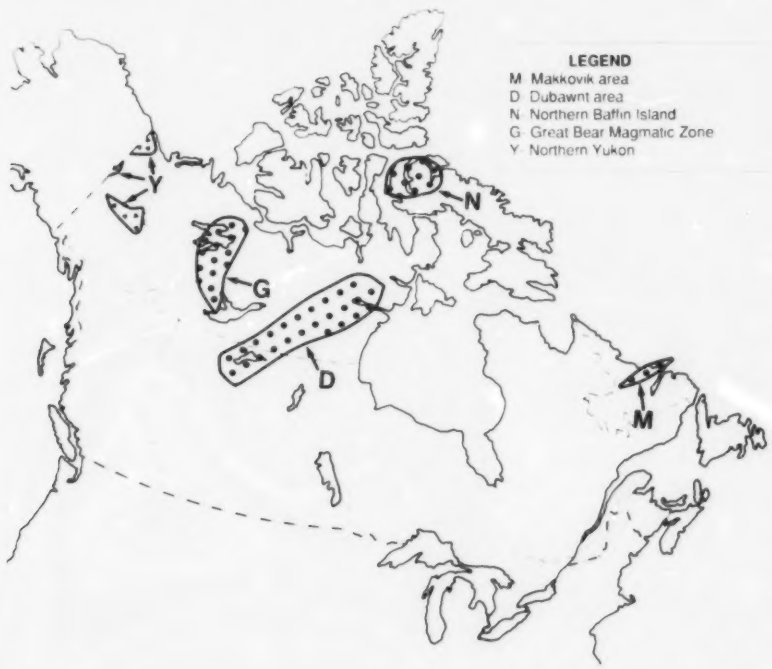
Additional new uranium-bearing regions may be outlined in Canada as a result of further studies on geologically similar areas outside Canada. Areas where the discovery of Olympic Dam-type polymetallic deposits is most likely are shown in Figure 9 [6]. They are the Slave Province in the Northwest Territories; the belt between Saskatchewan's Athabasca Basin and the Baker Lake/Thelon Basin area in the Northwest Territories; the Central Mineral Belt in Nain Province, Labrador; the Wernecke Mountains in the Yukon; and perhaps the north end of Baffin Island.

There is also modest potential in Canada for the discovery of so-called "young uranium" deposits. Such near-surface, low-grade uranium deposits are difficult to find using conventional gamma-radiation detectors. In British Columbia's semi-arid Okanagan area, deposits containing a thousand tonnes of uranium could be economic. In the bog/swamp deposits of northern British Columbia, Manitoba, New Brunswick and Newfoundland, the uranium content is in the low tens of tonnes, possibly rendering them uneconomic.

Uranium Exploration Activities

In terms of total expenditures, uranium exploration activity in Canada remained close to $35 million annually from 1984 to 1987. In 1988, however, exploration spending reached $59 million, related mainly to the advanced exploration efforts at the Cigar Lake and Midwest projects, where shaft sinking was

Figure 9 : *Areas in Canada with Potential for Discovery of Olympic Dam - Type Deposits*



SOURCE: GSC/EMR

under way in 1988. Exploration and surface development drilling increased slightly in 1987, from 162 000 m in 1986, but it jumped 22 per cent in 1988 to over 200 000 m, as activity was centred on the developed and proven properties.

In 1988, the ten most active operators* accounted for 98 per cent of the $59 million total expenditure. In alphabetical order, they were Amok Ltd., Cameco - A Canadian Mining & Energy Corporation, Cigar Lake Mining Corporation, COGEMA Canada Ltd., Denison Mines Limited, Interuranium Canada Ltd., Minatco Limited, PNC Exploration (Canada) Co. Ltd., Uranerz Exploration and Mining Limited, and Urangesellschaft Canada Limited. [* In most cases, operators report the total expenditures of a joint venture and thus contributions by other parties are accounted for in the $59 million total.]

Seven of these ten operators are companies whose majority interests are held outside of Canada; five of those are supported, directly or indirectly, by their national governments in their uranium exploration efforts.

Responses to the 1989 URAG survey revealed the exploration programs of virtually all the companies or joint ventures active in uranium exploration in Canada; 34 companies participated in 54 active exploration projects, managed by 14 operators. Table 11 summarizes recent uranium exploration activity in Canada [7].

Figure 10 illustrates the trend in corporate participation in uranium exploration in Canada. Foreign-based companies have accounted for between one-half and two-thirds of the total expenditures in Canada in the 1980s. Although foreign involvement in uranium exploration in Canada is high, participation by U.S. firms has steadily decreased since 1984 and in 1988 represented less than 2 per cent of total expenditures.

The last NEA/IAEA "Red Book" [8] shows that both Canada's and Australia's shares of total Western world uranium exploration expenditures have remained constant since 1984, but in the United States expenditures have declined, the U.S.share dropping by half. However, expenditures in France remained high, accounting for over 40 per cent of the Western world total in 1986, illustrating the commitment to nuclear power in that country, and its desire to find indigenous supplies of uranium.

In Saskatchewan, 1988 uranium exploration efforts were focussed in the southeastern part of the Athabasca Basin, between Key Lake and Cigar Lake, along the Eagle Point and Collins Bay faults. Significant activity also took place on the Wolly Block, in the Carswell Structure of the western Athabasca Basin, and at the western limit of the Basin in northern Alberta. In the Northwest Territories, the greatest exploration effort was conducted on the northeast margin of the Thelon Basin .

Table 11. **Uranium Exploration Activity in Canada, 1976 to 1988***

Year	Total spent[a] *($million)*[b]	Total drilled[c] *(km)*	Million-dollar projects[d]
1976	44	155	4
1978	90	334	7
1980	128	503	24
1982	71	247	13
1984	35	197	12
1986	33	162	11
1987	37	164	12
1988	59	201	11

** Refer to Appendix 1 for more exploration activity data.*

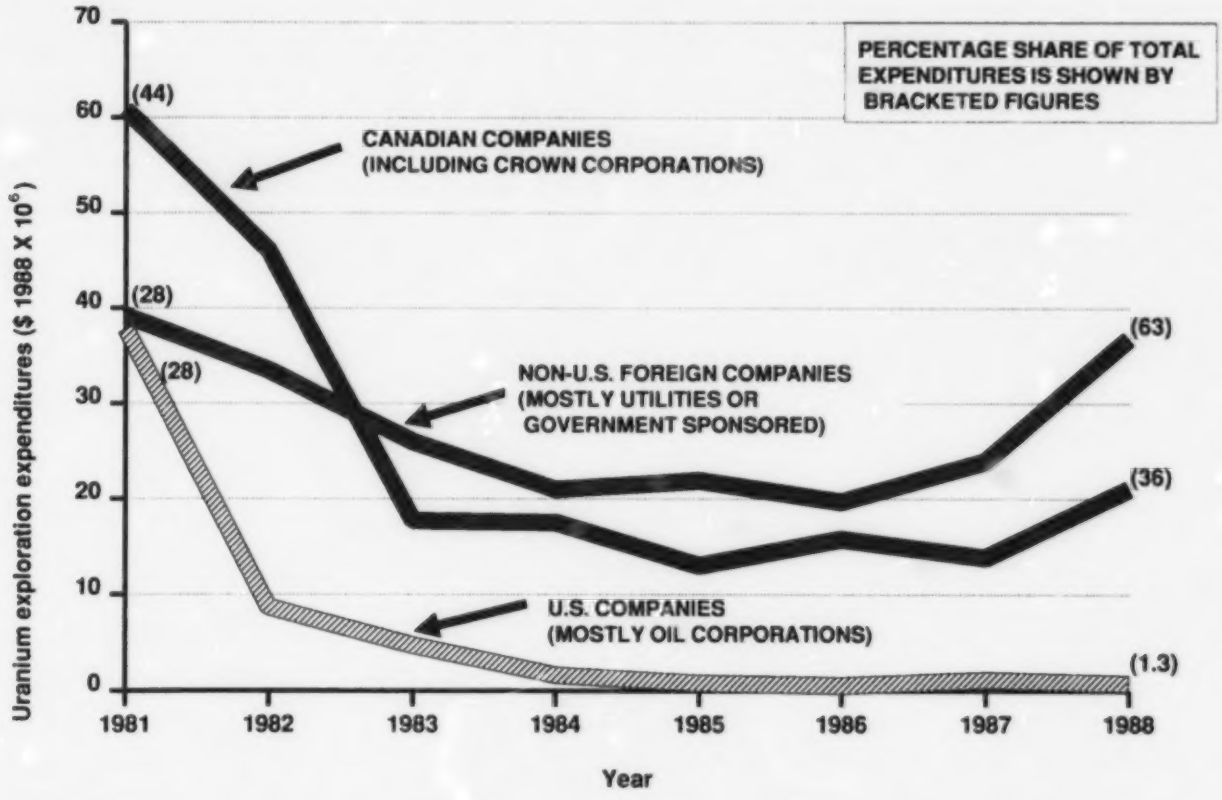
[a] Direct exploration and drilling expenditures

[b] Current (reporting year) dollars

[c] Exploration and surface development drilling; excludes development drilling on producing properties

[d] Number of projects where total expenditures exceeded $1 million

Figure 10 : *Trend in Uranium Exploration Expenditures in Canada*



SOURCE : UNEB/EMR

Many exploration programs are based on the application of conceptual genetic models, postulating deposit association with Proterozoic unconformities and with granitic basement domes.

Structural and lithological analysis led to the discovery of mineralization on the McArthur River property in Saskatchewan, between Key Lake and Cigar Lake. In the Maybelle River area of Alberta, at the western margin of the Athabasca Basin, a new field was discovered containing polymetallic uranium mineralization associated with the sub-Athabasca unconformity.

B) Uranium Availability

Uranium availability in the longer term will depend on a number of factors, the most important of which will be a continuing and developing demand for uranium, and continued access by all producers to the world's markets. Known deposits associated with existing production centres in Canada are capable of supporting significant output levels well beyond 2000. In addition, prospective production centres could increase Canada's output level, should markets warrant their development.

To depict a range of potential Canadian production possibilities beyond the turn of the century, four projections of production capability are summarized in Table 12. Scenarios I and II are simply extensions of the short-term projection (based on existing production centres) detailed in Part 1 of the report, whereas scenarios III and IV include potential output from those production centres that would likely be brought on stream given favourable developments in the uranium market; all rely only on resources that are recoverable at uranium prices of $150/kg U or less, i.e., those in the "A" or the "A + B" price range. If production is to exceed these projected levels, it must come from new discoveries, the realization of which would involve considerable exploration and development.

It is important to appreciate the long lead times and inherent risks that are associated with uranium exploration activities. It is not uncommon for 15 years to elapse between the start of an exploration program and first production from a successful discovery. With this in mind, current exploration programs should be focussed on meeting the longer-term needs of Canada and its trading partners. A loss of exploration momentum could jeopardize future supply opportunities.

Table 12. **Projections of Production Capability From Known Deposits in Canada**

Year	Tonnes U contained in concentrates			
	I	II	III	IV
1990	11 400	11 400	11 400	11 400
1995	10 000	11 600	11 200	16 300
2000	6 200	9 100	7 400	16 100
2005	3 900	5 400	5 100	12 400
2010	3 900	5 400	3 900	10 000
2015	3 000	4 600	3 000	6 900
2020	470	470	470	470
2025	470	470	470	470
2030	470	470	470	470

I - Existing production centres supported only by resources in the A price category.

II - Existing production centres supported by resources in the A + B price category.

III - Existing plus Planned and Prospective production centres supported only by resources in the A price category.

IV - Existing plus Planned and Prospective production centres supported by resources in the A + B price category.

2. REQUIREMENTS

A) World Outlook for Nuclear Power Growth*

Future requirements for Canadian uranium will depend on the growth in nuclear power capacity in the electricity generating systems of Canada and its trading partners.

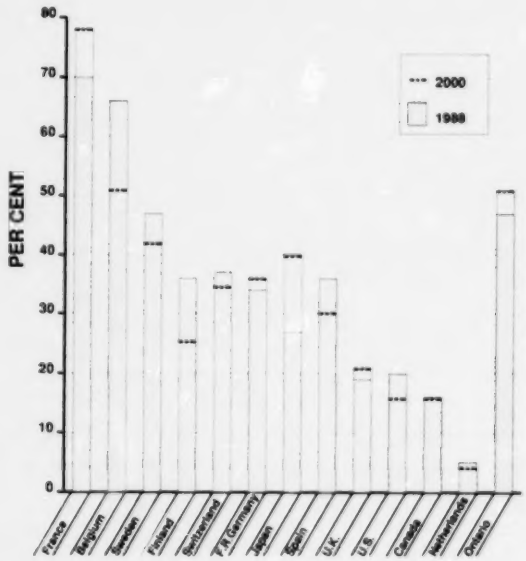
Projections of installed nuclear power capacity have been revised downward in recent years as a result of the competition from coal and gas, efforts to introduce energy conservation measures in several countries, and negative public opinion. However, forecasts still reflect steady growth in the contribution that nuclear power will make to world electricity supply, as shown in Figure 11 [9].

Canada's total installed nuclear capacity in the year 2000 is expected to reach 16 000 MWe requiring about 2 100 tU per year. Nuclear energy will then be providing about 16 per cent of the electricity supply in Canada and about half in Ontario.

Installed nuclear power capacity (net) in the Western world is expected to grow from about 275 000 MWe in 1989 to between 600 000 and 860 000 MWe by the year 2030. The actual rate will depend upon the economic growth rate and the related electricity requirements, and on the extent to which nuclear power will penetrate the electricity market. Related world uranium requirements could rise from the current annual level of 42 000 tU to between 64 000 and 109 000 tU by the year 2000 [10].

The future of nuclear power in the post-2000 period might very well depend on decisions taken during the next decade with regard to the environment. There is a growing awareness that nuclear power plants do not contribute to global warming, as do fossil-fuel plants. Rising concern about the emission of CO_2 and other gases that contribute to the greenhouse effect could well trigger an increase in orders for nuclear power plants, and lead to a reversal of the recent downward trend in nuclear power capacity projections.

Figure 11 : *Nuclear Share of Electricity Generated in Selected Countries, 1988 and 2000*



SOURCE : OECD AND ONTARIO HYDRO

* *World, as used here, excludes the U.S.S.R., Eastern Europe and the People's Republic of China.*

B) Demands on the Uranium-Producing Industry

Canada is the world's leading producer and exporter of uranium (see Figure 7). Moreover, it is among the leaders in terms of estimated uranium resources in all categories, and accounts for a major proportion of the world's low-cost Reasonably Assured Resources.

The NEA/IAEA's* most recent assessment of world uranium supply illustrates that Canada is one of the most promising countries for the discovery of additional uranium resources [8/10]. Canada has been a reliable uranium supplier to the world market for more than 40 years, and the Canadian government is committed to maintaining that role. Given its production capabilities and potential for additional discoveries, there is every reason to be confident that Canada can maintain its leading role in the world uranium market, while continuing to supply its domestic needs.

* *NEA - Nuclear Energy Agency of the Organisation for Economic Co-operation and Development*
IAEA - International Atomic Energy Agency

APPENDICES

APPENDIX 1 : URANIUM EXPLORATION STATISTICS

A. Uranium Exploration Drilling and Surface Development Drilling Activity in Canada*, 1981 to 1988

Province or territory	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*
				(thousands of metres)				
Saskatchewan	300.7	213.5	120.5	165.8	164.4	153.9	153.2	184.2
Northwest Territories	22.6	21.5	17.6	17.1	17.2	3.9	5.5	9.6
Quebec	18.5	12.4	13.4	14.1	1.7	0.0	0.0	0.0
Nova Scotia	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ontario	3.0	0.0	1.4	0.0	0.0	0.0	1.1	2.0
New Brunswick	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Newfoundland	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manitoba	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alberta	0.6	0.0	0.0	0.0	0.0	4.3	4.2	5.9
Yukon Territory	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
British Columbia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unspecified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals (rounded)	**359**	**247**	**153**	**197**	**183**	**162**	**164**	**202**

* *'Exploration drilling' refers to drilling done in search of new uranium deposits or extensions to known uranium deposits and to drilling at the location of a discovery up to the time that the company decides that sufficient ore has been delineated to justify commercial exploitation.*

'Surface development drilling' refers here to drilling subsequently done to determine more precisely a deposit's size, grade and configuration, and excludes development drilling on producing properties.

APPENDICES

APPENDIX 1 : URANIUM EXPLORATION STATISTICS

B. Uranium Exploration Expenditures in Canada*, 1981 to 1988

Province or territory	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*
	(millions of current Canadian dollars)							
Saskatchewan	60.8	47.9	27.3	24.8	23.5	28.9	32.7	50.1
Northwest Territories	23.6	13.2	7.3	6.4	6.2	2.5	2.7	6.5
Quebec	8.8	8.4	5.6	3.3	1.0	0.05	0.0	0.0
Nova Scotia	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Newfoundland	1.6	0.3	0.4	0.4	0.3	0.0	0.05	0.0
Ontario	0.9	0.4	0.2	0.0	0.0	0.0	0.1	0.3
New Brunswick	0.8	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Yukon Territory	0.7	0.3	0.0	0.06	0.2	0.2	0.0	0.0
Manitoba	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alberta	1.1	0.0	0.0	0.06	0.4	0.8	1.4	1.7
British Columbia	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.09
Unspecified	0.5	0.0	0.0	0.06	0.2	0.07	0.1	0.0
Totals (rounded)	**102**	**71**	**41**	**35**	**32**	**33**	**37**	**59**

** Expenditures on exploration and surface development drilling and all other costs directly associated with uranium exploration activities, excluding land acquisition. Overhead charges not directly associated with such activities are not included.*

APPENDICES

APPENDIX 1. URANIUM EXPLORATION STATISTICS

C. Total Expenditures and Coverage of Government-Sponsored Radiometric and Geochemical Surveys

Year	*Area covered*		*Expenditures*[a]		
	Radiometric	Geochemical[b]	Radiometric	Geochemical	Total
	(km^2)		*($ million)*		
1975 - 1982*	2 116 000[c] 56 000[d]	1 323 000	10.084	10.597	20.681
1983	19 500[c] 22 500[d]	99 000	0.397	0.784	1.181
1984	75 500[c] 22 000[d]	96 000	0.616	0.647	1.263
1985	34 000[d]	160 400	0.640	1.138	1.778
1986	57 000[c] 25 500[d]	184 100	0.738	1.568	2.306
1987	15 500[d] 1 600[e]	143 000	0.450	1.854	2.304
1988	13 000[d] 6 500[e]	108 900	0.550	1.538	2.088
1989[f]	15 000[d] 5 000[e]	51 700	0.475	0.840	1.315
Total	**2 484 600**	**2 116 100**	**13.950**	**18.976**	**32.916**

[a] *In $Cdn for the survey year, includes federal and provincial funding. Government expenditures on exploration drilling are nil.*

[b] *Includes provincial surveys to National Geochemical Reconnaissance (NGR) standards.*

[c] *5-km line spacing*

[d] *1-km line spacing*

[e] *Less than 1-km line spacing*

[f] *Estimate*

* *Pre - 1975 data not reported*

Note: *It should be noted that these surveys have been designed since their inception for the purpose of assisting mineral exploration and geological mapping in general, in addition to their specific relevance to uranium.*

APPENDICES

APPENDIX 2

DEFINITIONS OF RESOURCE AND PRODUCTION TERMINOLOGY

In its annual uranium resource assessment, the Uranium Resource Appraisal Group (URAG) divides its estimates into five separate categories reflecting different levels of confidence in the quantities reported. These categories are further separated into three levels of exploitability related to the current uranium price.

The following definitions and terms used by URAG are in harmony with those used by Energy, Mines and Resources Canada (EMR) for non-fuel mineral and coal resource assessment.

Ore	A natural mineral-bearing substance that can be recovered by mining and from which one or more commodities can be extracted economically under conditions specified at the time of the appraisal.
Measured ore	Refers to ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, or drill-holes, and for which grade is computed from adequate sampling. The sites for inspection, sampling and measurement are so closely spaced and the geological character is so well defined that the size, shape and mineral content are well established. The tonnage and grade should refer to ore recoverable by mining with due regard for dilution.
Indicated ore	Refers to ore for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geological evidence. The openings or exposures available for inspection, measurement and sampling are too widely or inappropriately spaced to outline the ore completely or to establish its grade throughout.
Inferred ore	Refers to ore for which quantitative estimates are based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. Estimates are based on assumed continuity or repetition for which there is geological evidence; this evidence may include comparison with deposits of similar types. Bodies that are completely concealed, but for which there is some geological evidence, may be included. Estimates of inferred ore should include a statement of the specific limits within which the inferred material may lie. These limits vary depending upon the characteristics and knowledge of the orebodies.
Prognosticated resources	Refers to estimated tonnages beyond specific limits established for inferred ore. They may include tonnages of portions of identified orebodies or of concealed satellite orebodies, the existence of which can be assumed along well-established geological trends associated with known deposits. The attributes of prognosticated resources are, as a rule, derived by extrapolation from identified deposits or by quantification of geological information.

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Speculative resources	Refer to estimated tonnages in deposits thought to exist on the basis of indirect indications and geological extrapolations in unexplored areas or in areas where only occurrences are known. These resources would be geologically comparable to resources in known deposits that are judged to be mineable at prices below a given level.
Reserves	Refer only to those measured and indicated resources that could be mined at the uranium market price as determined at the time of the assessment (equivalent to block 1A of Figure A-1) unless another price is specified.
Adjusted recoverable resources	Refer to the sum of resources in the measured, indicated and inferred categories, weighted by factors of 1.0, 0.8 and 0.7, respectively, recoverable from mineable ore at prices of $150/kg U or less. The term was developed for the purpose of monitoring domestic uranium resource adequacy, and, as such, factors in only those resources of Canadian producers that are marketing uranium.

For categorization by price level (i.e., level of economic exploitability), cut-off grades are chosen that cover all costs of production after due consideration of processing losses, plus any required forward capital costs. The difference between the cut-off grade and the average grade of the resources for each individual deposit is then examined to determine if the difference is sufficient to carry such items as taxes and royalties, head office overhead, forward exploration and development costs, and an acceptable rate of return on invested capital (i.e., costs associated with the use of capital). If the difference between the chosen cut-off grade and the average grade is judged sufficient, the tonnage is taken to be mineable at a price below the stated limit.

Except where otherwise stated, resource estimates in the measured, indicated and inferred categories refer to quantities of uranium recoverable from mineable ore, as opposed to quantities of uranium contained in mineable ore, or uranium contained in situ (i.e., deductions have been made for both mining and ore-processing losses). In the case of the prognosticated category, resource estimates are expressed in terms of quantities of uranium contained in mineable ore. Speculative resource estimates are expressed as *in-situ* quantities.

For national and international purposes, Canadian resource estimates are often quoted in terms of the international uranium resource definitions employed by the NEA and the IAEA, in their assessments of world uranium resources, which are prepared as a joint exercise on a regular basis. The terms Reasonably Assured Resources (RAR) and Estimated Additional Resources (EAR) and their definitions were first developed in 1964, and have been retained with some modifications since then. It is pertinent to note that, in 1975, the NEA/IAEA changed their resource definitions to refer to 'cost' instead of 'price,' while Canada has retained the price classification.*

The term Speculative Resources was introduced by the NEA/IAEA in 1978, in the recognition that assessments covering only RAR and EAR represented an incomplete appraisal of the world's uranium resources. In late 1982, the NEA/IAEA redefined their EAR category to distinguish between the discovered and the undiscovered

* *For purposes of international comparison Canada's three defined 'price' categories may be considered equivalent to the NEA/IAEA's three defined 'cost' categories, from the lowest to the highest, respectively. The three defined cost/price categories are illustrated by blocks labelled A, B and C, respectively, in Figure A-1.*

components of those additional resources that are expected to occur in association with known deposits. These two components have been termed Estimated Additional Resources - Category I (EAR-I) and Estimated Additional Resources - Category II (EAR-II), respectively.

The NEA/IAEA resource definitions shown below include minor editorial changes that were adopted by the NEA/IAEA for their 1989 exercise. The relationship of these definitions to those used in EMR's annual assessment of uranium resources is illustrated in Figure A-1.

Figure A-1 : *Classification Scheme for Resources of Recoverable Uranium*

SOURCE : NEA/IAEA and EMR

Reasonably Assured Resources (RAR)

Refers to uranium that occurs in known mineral deposits of delineated size, grade and configuration such that the quantities which could be recovered within the given production cost ranges, with currently proven mining and processing technology, can be specified. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. Reasonably Assured Resources have a high assurance of existence.

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Estimated Additional Resources -Category I (EAR-I)	Refers to uranium in addition to RAR that is inferred to occur, mostly on the basis of direct geological evidence, in extensions of well-explored deposits, or in deposits in which geological continuity has been established but where specific data, including measurements of the deposits, and knowledge of the deposits' characteristics are considered to be inadequate to classify the resource as RAR. Estimates of tonnage, grade and cost of further delineation and recovery are based on such sampling as is available and on knowledge of the deposit characteristics as determined in the best-known parts of the deposit or in similar deposits. Less reliance can be placed on the estimates in this category than on those for RAR.
Estimated Additional Resources - Category II (EAR-II)	Refers to uranium in addition to EAR-I that is expected to occur in deposits for which the evidence is mainly indirect and which are believed to exist in well-defined geological trends or areas of mineralization with known deposits. Estimates of tonnage, grade and cost of discovery, delineation and recovery are based primarily on knowledge of deposit characteristics in known deposits within the respective trends or areas and on such sampling, geological, geophysical or geochemical evidence as may be available. Less reliance can be placed on the estimates in this category than on those for EAR-I.
Speculative Resources (SR)	Refers to uranium, in addition to EAR-II, that is thought to exist, mostly on the basis of indirect evidence and geological extrapolations, in deposits discoverable with existing exploration techniques. The location of deposits envisaged in this category could generally be specified only as being somewhere within a given region or geological trend. As the term implies, the existence and size of such resources are highly speculative.

In presenting their definitions, the NEA/IAEA emphasize that the distinctions drawn between the four categories of resources (RAR, EAR-I, EAR-II and SR), based on differing degrees of geological evidence, make it essential that each category be regarded as a discrete entity. Therefore, great care should be taken in the use of resource estimates (e.g., not summing estimates of all four categories to obtain 'total resources'). For their 1989 assessment, the NEA/IAEA adopted the following two geological terms:

Uranium occurrence	Is a naturally occurring anomalous concentration of uranium.
Uranium deposit	Is a mass of naturally occurring mineral material from which uranium could be exploited at present or in the future.

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With the increased emphasis that has been placed on projections of production capability as illustrations of uranium supply possibilities, it was necessary to formalize a number of terms used in the description of such projections. The NEA/IAEA introduced the following terms in their December 1983 assessment of world uranium supply. These terms are used throughout this report.

Production centre

As referred to in this report, is a production unit consisting of one or more ore processing plants, one or more associated mines and the resources that are tributary to them. Production centres have been divided into four classes, as follows:

A) Existing Production Centres are those that currently exist in operational condition and include those plants which are closed down but could be readily brought back into operation.

B) Committed Production Centres are those that are either under construction or are firmly committed for construction.

C) Planned Production Centres are those that are planned, based on feasibility studies that are either completed or under way, but for which construction commitments have not yet been made. This class also includes those plants that are closed which would require substantial expenditures to bring them back into operation.

D) Prospective Production Centres are those that could be supported by tributary RAR and EAR-I, i.e., '*known resources,*' but for which construction plans have not yet been made.

Production capacity

Denotes the nominal level of output, based on the design of the plant and facilities over an extended period under normal commercial operating practice.

Production capability

Refers to an estimate of the level of production that could be practically and realistically achieved under favourable circumstances from the plant and facilities at any of the types of production centres described above, given the nature of the resources tributary to them. (Normally, projections of production capability are supported only by RAR and/or EAR-I.)

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APPENDIX 3

CANADIAN URANIUM EXPORT POLICY

Canadian uranium export policy has been designed and modified over the years with the primary objective of maintaining Canada's role as a reliable and competitive long-term supplier for its trading partners, while seeking to obtain optimum benefit for Canada from the development of its uranium resources.

There is an overriding policy objective that Canada's uranium not be used in connection with the production of nuclear explosive devices. In the case of non-nuclear weapons states, sales are allowed only to those countries that have made a general commitment to non-proliferation by either having ratified the international Treaty on Non-Proliferation of Nuclear Weapons *(NPT)* or having taken an equivalent binding step, and that have thereby accepted international inspection through the International Atomic Energy Agency (IAEA) of all of their nuclear facilities.

Uranium exports can proceed only to those states (both non-nuclear and nuclear weapons states) that have undertaken to accept, in a formal agreement, a number of additional requirements covering: *(a)* assurance that Canadian-supplied nuclear material, equipment and technology not be used for explosive purposes; *(b)* retransfer to third parties; *(c)* the use of highly enriched uranium and plutonium derived from Canadian material; *(d)* physical protection; and *(e)* standby safeguards. This last provision would come into effect should IAEA safeguards ever cease to apply for any reason.

Elements of export policy are in place which seek to ensure adequate supplies of uranium for domestic needs, to provide fair returns to Canadians from exportable surpluses, and to realize opportunities for further processing. For example, pricing terms in uranium export contracts must provide for an equitable balance of benefits and risks and be in general agreement with those being obtained by Canadian and international producers for uranium under contracts of similar duration. Unless exemptions are granted, uranium must be upgraded to the maximum extent possible in Canada before export, as long as Canada's conversion facilities have the capacity and are generally competitive.

Exemptions to the further processing requirements are granted in cases where end-users have existing, bona-fide, arm's-length conversion contracts in place, dated prior to January 1, 1980, the termination of which would not be possible without significant financial hardship. With the implementation of the Canada/U.S. Free Trade Agreement, exemptions will also be granted in cases where the Canadian uranium will be refined and converted in the United States for actual consumption in a reactor in the U.S., or in cases where the Canadian uranium will be refined, converted and enriched in the United States prior to export to a third country.

All uranium export contracts are reviewed by federal government authorities to ensure that they meet the intent of these export policy objectives. In order to export uranium under a contract that has been found to be consistent with these objectives, the exporter must apply to the regulatory authorities (at the time of export, or annually in the case of multi-year contracts) for the necessary export licence and export permit.

The uranium export contract review process is relatively smooth and efficient, and the related policies are applied in a realistic and pragmatic manner.

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APPENDIX 4

FOREIGN OWNERSHIP IN THE URANIUM MINING SECTOR

In December 1987, Canada's Minister of State for Forestry and Mines announced a new policy on non-resident ownership in the uranium mining sector. The new policy is designed to encourage investment in Canada's uranium mining industry, and to promote economic development, exports and jobs for Canadians. It will provide considerable flexibility to investors, both Canadian and foreign, and should significantly facilitate the efforts of those interested in financing the development of recent Canadian uranium discoveries.

The primary objective of the new policy is a 51 per cent level of Canadian equity in an individual uranium property when production begins. However, lower levels of Canadian ownership would be permitted if Canadian control can be clearly demonstrated. Only in cases where Canadian partners cannot be found would exemptions to the policy be considered, and these would require Cabinet approval. These new criteria are considerably more liberal than those in previous policy. There continue to be no restrictions on foreign participation in Canada's uranium industry at the exploration stage.

APPENDIX 5

ENERGY CONVERSION FACTORS

Requests for factors to convert quantities of uranium into common units of energy for comparison with other energy sources have occurred during recent years with increasing frequency. In response to these needs, the NEA/IAEA developed such factors for various reactor types for inclusion in their 1988 *Red Book*. These factors were used, together with standard conversion and energy equivalent factors for fossil fuels, to arrive at the thermal energy equivalents utilized in the construction of Figure 1. Readers may find that the factors provided on the page opposite are useful.

APPENDICES

ENERGY CONVERSION FACTORS

1 tU utilized in a CANDU once-through fuel cycle = 0.691×10^{15} Joules

or

1 tU utilized in a typical LWR/PWR once-through fuel cycle = 0.45×10^{15} Joules

♦

10^{12} Joules = 1 Terajoule (TJ) = 23.885 Tonnes of Oil Equivalent (TOE)

and

1×10^{6} TOE (MTOE) = 42 Petajoules (10^{15} Joules)

♦

1 MTOE = 93 tU
(in typical LWR/PWR reactor)

or

1 MTOE = 61 tU (in CANDU reactor)

or

1 MTOE = 84 tU (for energy equivalent of Canadian uranium production)
[assumes 85% exported for LWR/PWR use and 15% for domestic use]

♦

1 MTOE = 7.58×10^{6} barrels of oil
1 MTOE = 1.111×10^{9} m^3 natural gas
1 MTOE = 1.5×10^{6} tonnes of hard coal
1 MTOE = 3.0×10^{6} tonnes of soft coal

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Note: OECD and IAEA documents are available in Canada through:

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